III. "On the Structure of the so-called Apolar, Unipolar, and Bipolar Nerve-cells of the Frog." By LIONEL BEALE, M.B., F.R.S., F.R.C.P., Professor of Physiology and of General and Morbid Anatomy in King's College, London, and Physician to King's College Hospital. Received May 7, 1863.

(Abstract.)

The author adverts to the opinion generally received with regard to the existence of *apolar*, *unipolar*, *bipolar*, and *multipolar* nerve-cells, and observes that if cells having such very different relations to the nerve-fibres they are supposed to influence, as apolar, unipolar, and multipolar cells, do actually exist, as many different kinds of action must be admitted. For it is hardly likely that a nerve-cell unconnected with any fibre can affect the fibres at a distance from it in the same way as a cell acts upon fibres which are in structural continuity with it. Neither is it probable that a cell with but one fibre proceeding from it can constitute an organ which acts upon the same principle as the cell from which two or more fibres proceed. If no fibre, or but one fibre proceeds from certain cells, the formation of complete nervous circuits, at least in these instances, is impossible; and if it be admitted that circuits do not exist in every case, a strong argument is advanced against the existence of such complete circuits as a necessary or fundamental condition of a complete nervous apparatus. But if it can be shown, on the other hand, as the author maintains is the case, that all the supposed apolar and unipolar cells have at least two fibres proceeding from them, the fact must be accepted in favour of the view that such complete circuits may exist, while the fact that the fibres connected with many cells have been seen to proceed in opposite directions some distance after leaving the cell, is a very strong argument in favour of such general inference, and at the same time an explanation of many arrangements which are observed constantly in connexion with nerve-fibres in various tissues.

Many observers have described *apolar* and *unipolar* cells in ganglia in different parts of the frog. The author, on the other hand, has failed to discover any apolar or unipolar cells in this or in any other animal, and considers that the apparent absence of fibres, and the presence of one fibre only in connexion with a cell, result from the defective modes of preparation generally employed. He maintains

that every nerve-cell, *central* or *peripheral*, has at least two fibres proceeding from it*. In many cases he has demonstrated that these fibres pursue opposite directions, and he considers that such an arrangement is general, and therefore necessary. The author considers himself justified in drawing the following conclusions from observations he has made during the last three years.

1st. That in all cases nerve-fibres are in bodily connexion with the cell or cells which influence them, and this from the earliest period of their formation.

2nd. That there are no apolar cells, and no unipolar cells, in any part of any nervous system.

3rd. That every nerve-cell, central or peripheral, has at least two fibres in connexion with it.

Though the present inquiry is limited to the structure of the particular cells connected with the ganglia in different parts of the frog, the author has studied the arrangement of nerve-cells and nerve-firbes in nervous centres, as well as at their peripheral distribution, in many different animals.

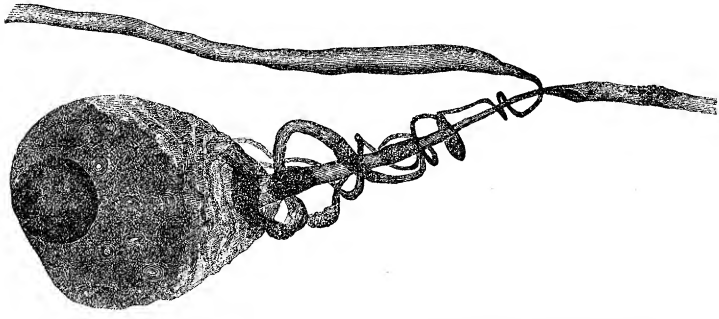
1. *General description of the ganglion-cells connected with the sympathetic and other nerves of the frog.*

The general form of these cells is oval or spherical; but the most perfectly formed ganglion-cell is more or less pear- or balloon-shaped in its general outline, and by its narrow extremity is continuous with nerve-fibres which may be followed into trunks.

The figure represents a well-formed ganglion-cell from a ganglion close to one of the large lumbar nerves of the little green tree-frog (*Hyla arborea*). The substance of the cell consists of a more or less granular material, which by the slow action of acetic acid becomes

* The word "cell" is only used in a general sense, as being shorter and more convenient than "elementary part." It consists merely of, 1st, matter in a living active state (*germinal matter*), and 2nd, matter resulting from changes occurring in this (*formed material*). In the figure, what is ordinarily termed "nucleus" and "nucleolus" consists of germinal or living matter, while the matter at the lower part of the cell and the nerve-fibres are formed material. A nerve-fibre cannot produce a new nerve-fibre, but the "nucleus" or germinal matter of a nerve-fibre can produce new nerve-fibre. The formed matter never produces matter like itself. Germinal matter can produce matter like itself, and from this formed material may result.

decomposed, oil-globules being gradually set free. Near the fundus or rounded end is seen the very large circular nucleus with its nucleolus. In some of these cells, at about the central part or a little higher, are a number of oval nuclei, some of which are in connexion with fibres. The matter of which the mass of the cell consists gradually diminishes in diameter, and contracts so as to form a fibre, in which a nucleus is often seen. At the circumference of the cell, about its middle, the material seems gradually to assume the form of fibres, which contain numerous nuclei, and these pass around



So-called "unipolar" nerve-cell, with, 1st, a *straight*, and 2nd, a *spiral* fibre emanating from it. The fibres continuous with these are seen to pursue opposite directions. Magnified 700 linear.

$\frac{1}{10000}$ 1000th of an inch × 700.

the first fibre in a spiral manner. Thus in the *fully formed cell a fibre comes from the centre of the cell* (*straight fibre*), *and one or more fibres* (*spiral fibres*) *proceed from its surface.* These points are represented in the figure*.

2. *On the formation of ganglion-cells in the fully formed frog.*

This subject is arranged under the three following heads, but as it would not be intelligible without figures, it will not be given in abstract. The development of these cells and many other structures may be studied in the fully formed animal as well as in the embryo.

a. Ganglion-cells developed from a nucleated granular mass like that which forms the early condition of all tissues.

b. Ganglion-cells formed by the division or splitting up of a mass like a single ganglion-cell.

* The specimen from which this drawing was taken has been seen by many observers.

c. Ganglion-cells formed by changes occurring in what appears to be the nucleus of a nerve-fibre.

3. *Further changes in the ganglion-cell after its formation.*

Under this head the movement of the cell from the point where its growth commenced is described. It is shown that the two fibres, which at first seem to come from opposite extremities of the cell, lie parallel to each other. They increase in length, and subsequently one is seen to be twisted round the other, as shown in the figure. Sometimes the fibres below the point where the spiral arrangement exists run parallel for a long distance, but at length pursue opposite directions. The author considers that the formation of the ganglion-cell commenced at the point where the fibres diverge, and that subsequently the cell moved away,—the parallel fibres, which at length become straight and spiral, being gradually formed or drawn out as it were from the cell.

4. *Of the spiral fibre of the fully formed ganglion-cell.*

The spiral fibre or fibres can be shown to be continuous with the material of which the body of the cell is composed, as well as the straight fibre, but the former are connected with its surface, while the latter proceeds from the deeper and more central part of its substance.

There are many nuclei in connexion with the spiral fibre, and several nuclei of the same character imbedded in the substance of the mass of which the cell is composed. These latter nuclei seem to be connected with an earlier condition of the matter which becomes, when more condensed, spiral fibre. A great difference is observed with regard to the extent of the spiral fibre in cells of different ages. In the youngest cells the fibres near the cell are both parallel to each other, but as the cell grows one is seen to be coiled round the other; and the number of coils increases as the cell advances in age, while the matter of which the fundus of the cell is composed gradually becomes less—apparently in consequence of undergoing conversion into fibres. Nuclei are found in the course of the straight fibre, as well as in connexion with the spiral fibre. Nuclei have been demonstrated in connexion with the dark-bordered fibres near their origin and near their distribution in all tissues.

Next follows a discussion "on the essential nature of the changes

occurring during the formation of all nerve-cells, and on the formation of spiral fibres," but this is not adapted for an abstract. The term "nucleus" is only employed in a general sense. The author believes that the "nucleus," "nucleolus," and centres within the latter ("nucleoluli") merely represent centres of different ages. He considers that the matter of the nucleus becomes gradually transformed into the formed matter around it, and generally, that these bodies are merely centres which arise in pre-existing centres. He maintains that from the outer formed matter connected with the fibres new nerve-cells could not be produced, while he holds that from the nuclei, nucleoli, and contained centres, entirely new and complete cells could be evolved. So he considers that the difference in the properties and powers of the formed matter on the one hand, and the nuclei and nucleoli on the other, depends upon these two kinds of matter having arrived at different stages of existence. That which is formed cannot form new formed matter, nor appropriate nutrient material; but the living germinal matter of the nucleus can be resolved into formed matter, and it can appropriate inanimate pabulum, and confer upon it the same wonderful (vital) powers which it possesses itself, and which were communicated to it from pre-existing germinal matter.

7. *Of the fibres in the nerve-trunks continuous with the straight and spiral fibres of the ganglion-cells.*

The conclusions upon this important question are as follows:—

1st. That in some instances very fine fibres, not more than the $\frac{1}{60,000}$th of an English inch in diameter, are alone continuous with both straight and spiral fibres of the ganglion-cell.

2nd. That a dark-bordered fibre may be traced to the ganglion-cell as the *straight fibre*, while the spiral fibres are continued on as very fine fibres.

3rd. That the spiral fibres may be continued onwards as a dark-bordered fibre which may even be *wider*, at least for some distance, than the fibre continued from the straight fibre.

4th. That both straight and spiral fibres may be continuous with dark-bordered fibres.

It is therefore quite certain that the spiral fibre is not connective tissue, although the author considers it probable that many German

observers may adopt this view until they have an opportunity of seeing the fibres themselves.

8. *Of the ganglion-cells of the heart.*

The author's conclusions are quite opposed to those of Kölliker, who states that all the cells are *unipolar*, and that the fibre always passes in a peripheral direction, also that the transcurrent fibres of the vagus have no connexion with these cells. The author, on the contrary, affirms that the cells have at least *two fibres coming from them*, that some of the fibres pass towards the heart, and others towards the brain. He regards it as very probable that many at least of these ganglion-cells are connected with fibres of the vagus. Kölliker has also stated (1860) that many apolar cells could be seen in the heart, ganglia, and in the bladder. The author has been able to demonstrate fibres in connexion with so many cells which appeared devoid of fibres, that he considers himself justified in denying the existence of apolar and unipolar cells altogether.

Next follow some observations on "the ganglion-cells and nerves of arteries;" "on the connexion of the ganglion-cells with each other;" and the paper concludes with a description of the so-called "capsule" of the ganglion-cell, and a discussion on the nature and formation of the connective tissue and its corpuscles in the immediate neighbourhood of nerve-fibres.

The paper is illustrated with forty-seven drawings of the specimens, magnified from 700 to 1700 linear; and the author states that many of the specimens will probably retain the appearances he has copied for several months. All the preparations have been made in the same manner. An outline of the process has been already given in the author's previous communications, but the author is aware that it may be some time before the correctness of his conclusions is generally admitted, in consequence of the difficulty of preparing demonstrative specimens.

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